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Effects of the Abandoned Elizabeth Copper Mine on Fisheries Resources of the West Branch of the Ompompanoosuc River

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Penko, Michael

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U.S. Army Corps of Engineers, New England Division
424 Trapelo Road
Waltham, MA 02254-9149

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13. ABSTRACT *(Maximum 200 words)*

This study examines the impact of drainage from the Elizabeth Copper Mine on fisheries resources in the West Branch of the Ompompanoosuc River. The study, an extension of previous studies which found adverse effects on the water from the mine drainage, contains two major components: 1) an assessment of the impact of mine drainage on metal levels in blacknose dace and river sediments, and 2) a study of fish community composition and biomass upstream and downstream of the mine. Downstream of the mine, copper levels are significantly higher while zinc and manganese levels, although elevated and highly variable, are not significantly different from those upstream. Lead, iron, barium, and chromium levels show no change. Variations in metal levels is attributed to mine drainage and differences in grain size.

Analysis of the standing crop of forage species found and great reduction downstream of the mine. Elevated metal levels found in blacknose dace may be misleading as samples may have been contaminated by sediments attached to the extremities.

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EFFECTS OF THE ABANDONED ELIZABETH COPPER MINE ON FISHERIES RESOURCES OF THE WEST BRANCH OF THE OMPOMPANOOSUC RIVER

prepared for

State of Vermont

by

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

January 1990

EXECUTIVE SUMMARY

This study was conducted to examine the impact of drainage from the abandoned Elizabeth Copper Mine (South Strafford, Vermont) on fisheries resources in the West Branch of the Ompompanoosuc River. The study was designed to augment previous studies which found that the mine adversely effects water quality and fisheries resources in the river. The study had two main components: 1) an investigation of the impact of mine drainage on metal levels in blacknose dace and river sediments, and 2) a quantitative study of fish community composition and biomass upstream and downstream of the mine.

Fish and sediment samples for metal analysis were taken from one area upstream of the mine, and at three downstream locations. Replicate (n=3) samples were taken from each location. Fish community composition was determined at two locations upstream of the mine, and at two downstream locations.

River sediments downstream of the mine contained significantly higher copper levels than those from upstream stations. Zinc and manganese levels were also elevated downstream of the mine, but highly variable, and not significantly different from upstream stations. Mine drainage also had no significant effect on levels of lead, iron, chromium, or barium in river sediments. Cadmium levels were generally below detection limits at all stations. Variations in metal levels observed in river sediments were probably related both to mine drainage, and to differences in sediment grain size.

Fish tissue (whole body) analysis indicated that elevated levels of copper and other metals may occur in blacknose dace downstream of the mine. This conclusion is tenuous, however, because elevated levels of iron found in dace suggest that samples may have been contaminated by sediments adhering to gills or other external surfaces. Further analysis of tissues free of potential surface contamination (i.e. muscle tissue or internal organs) would be necessary to determine conclusively whether or not dace downstream of the mine have elevated metal levels.

Upstream of the mine the fish community was dominated by longnose dace, blacknose dace, and slimy sculpin. Brook trout and longnose sucker were predominant downstream of the mine. Although total fish standing crop upstream and downstream of the mine were similar (4.7 and 3.7 kg/ha, respectively), the standing crop of forage species was greatly reduced downstream of the mine.

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INTRODUCTION

STUDY AUTHORITY

Authority for the study is contained in Section 22 of the 1974 Flood Control Act (Public Law 93-251) as amended ("Planning Assistance to States") which authorizes cooperation with the states in preparation of plans for the development, utilization, and conservation of water resources.

This study was conducted by the New England Division of the U.S. Army Corps of Engineers at the request of the Vermont Department of Environmental Conservation (DEC).

STUDY PURPOSE AND SCOPE

This study was conducted to provide the Vermont DEC with information concerning the impact of drainage from the abandoned Elizabeth Copper Mine on fisheries resources of the West Branch of the Ompompanoosuc River. The mine is situated in east central Vermont, near the village of South Strafford (Figure 1). Previous studies have indicated that mine drainage is a significant point source of heavy metals and suspended sediments (Faro, 1977; Vermont Dept. of Water Resources, 1969; Trinchero, 1980; Barth, 1984; U.S. Army Corps of Engineers, 1983). Studies by Trinchero (1980) and Langdon (pers. commun.) suggest that mine drainage has had an adverse impact on fisheries resources of the river. This study was designed to further examine the impact of mine drainage on fisheries resources, and has two main components:

1) A study of levels of selected metals in blacknose dace and river sediments collected from upstream and downstream of the mine site.

2. A study of fish community composition and biomass upstream and immediately downstream of the mine site.

GENERAL SETTING

The Elizabeth Mine was discovered in 1793, and initially produced iron ore and iron sulfate (see Howard, 1969). The site was mined intermittently for copper, on a small scale, between 1830 and 1930. Extensive underground copper mining occurred from 1943 until the facility closed in 1958 (Barth, 1984). At present, the site consists of open mining pits, adits, abandoned buildings, and extensive tailing deposits. Surficial tailings at the site have high iron and sulfate content, and contain moderate levels of zinc, manganese, and copper. Trace amounts of chromium, lead, and mercury are also present in tailings (U.S. Army Corps of Engineers, 1989).

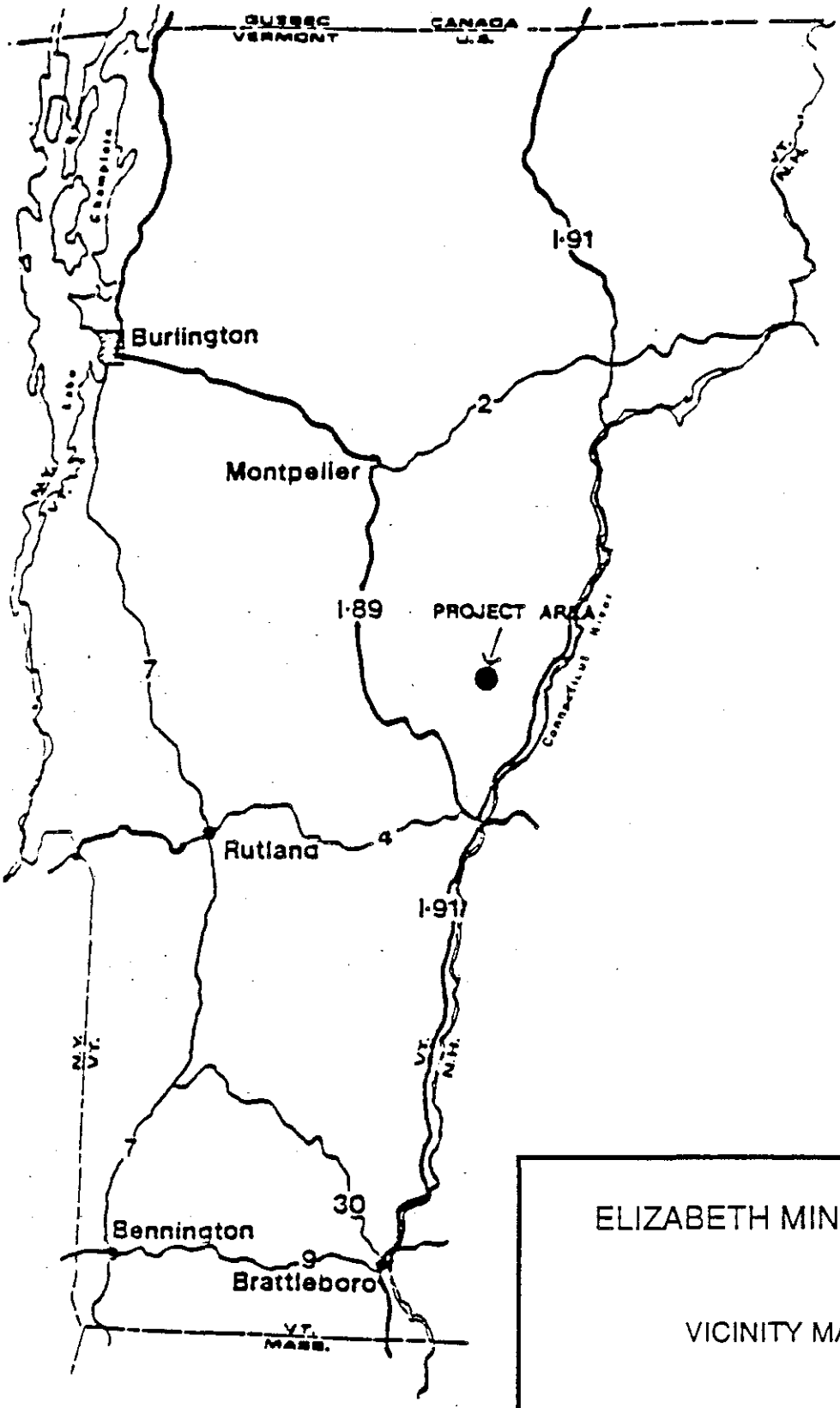
The Elizabeth mine is drained primarily by Copperas Brook, a small stream which flows into the West Branch of the Ompompanoosuc River (Figure 2). The brook originates upstream of the main tailings deposit, and passes through the tailing via a deteriorated system of concrete pipes.

The West Branch of the Ompompanoosuc originates about 10 miles upstream of Copperas Brook, and ends about 4.5 miles downstream, at its confluence with the East Branch of the Ompompanoosuc. From this point, the river flows about 0.75 miles to the U.S. Army Corps of Engineers Union Village flood control dam (see Figure 2). The Ompompanoosuc joins the Connecticut River about 5 miles downstream of the dam.

In the study area, the river ranges from about 30 to 40 feet wide upstream of the mine (near South Strafford), to about 75 feet wide near its confluence with the East Branch. Stream canopy cover is greater than 50 percent along upper reaches of the study area, but relatively sparse near the confluence with the East Branch. The river has an average drop in elevation of about 10 meters per kilometer (60 feet per mile) through the study area.

High levels of suspended sediments and dissolved metals occur in Copperas Brook downstream of the tailings deposits (Barth, 1984). Total metal load exported from the mine site via the brook is estimated to be about 330,000 kilograms/year (Barth, 1984). About 80 percent of this load is attributed to iron. Aluminum, is the next most important constituent (by weight), followed by copper, zinc, and relatively small amounts of lead and cadmium. An additional 8,600 kilograms/year of metals reach the river via drainage from a flooded air shaft located about 1500 feet upstream of Copperas Brook.

Elevated levels of dissolved metals, including copper, cadmium, iron, mercury, and zinc, occur in West Branch, and are frequently in excess of criteria set to protect sensitive aquatic life (U.S. Army Corps of Engineers, 1983). Elevated concentrations apparently result from both Elizabeth Mine drainage and from natural geologic sources upstream of the mine. Relative to natural sources, the mine appears to be a significant source of elevated levels of dissolved iron, copper, and possibly mercury.



ELIZABETH MINE SITE

VICINITY MAP

FIGURE 1

STUDY DESIGN AND METHODS

BLACKNOSE DACE AND SEDIMENT STUDY

Four sampling areas were established on the West Branch of the Ompompanoosuc River (Figure 2). One was situated upstream of Copperas Brook and other discharges from the Elizabeth Mine. The other sites were situated downstream of the confluence with Copperas Brook. Each sampling area was subdivided into three stations which were separated by a variable distance of at least 300 feet.

Twenty blacknose dace (Rhinichthys atratulus) and a sediment sample were collected from each station. Blacknose dace were selected for study because previous reports indicate that they are the most common forage species in the river (Langdon, pers. commun). Trout were not a suitable indicator species, because many of these fish present in the Ompompanoosuc may be transitory migrants from stocked tributary streams.

Sampling was conducted in early July of 1989. Fish were collected using a backpack mounted electroshocker. Upon collection, fish were rinsed in river water, wrapped in plastic wrap, labelled, bagged, and immediately frozen. Sediment samples were a composite of surface sediments collected with a plastic spoon from at least five locations within each station. Samples were placed in prewashed 100 ml plastic vials, labelled, and immediately frozen. Both fish and sediment samples were kept frozen until further processing in the laboratory.

Fish tissues were analyzed for metals (Ba, Cd, Cr, Cu, Fe, Pb, Mn, Zn) in the following manner. Fish were allowed to partially defrost, and the intact gastrointestinal tract was excised with a stainless steel blade. The blade was wiped after each fish was dissected to minimize potential contamination. After all 20 fish were dissected, they were rinsed three times with Milli-Q water. After each rinse, excess water was squeezed from the fish using a prewashed wooden tongue depressor. After the final rinse the 20 fish were homogenized in a Tekmar stainless steel tissuemizer and frozen. The tissuemizer was washed six times with Milli-Q water between successive samples.

About 5 grams of homogenized fish tissue was weighed directly into a 100 ml acid washed Kjeldahl flask. Twenty five ml of Ultrex grade concentrated nitric acid was added, and the flask heated to a slow boil. Samples were digested in this manner until about 5 ml of solution remained in the flask. Digests were cooled and quantitatively transferred to 50 ml volumetric flasks. Flasks were made up to volume with ultra pure water and filtered through 0.45 micron Nalgene filters. Digests were analyzed via Inductively Coupled Plasma (ICP) Spectroscopy by Chemrox, Inc. of Shelton Connecticut.

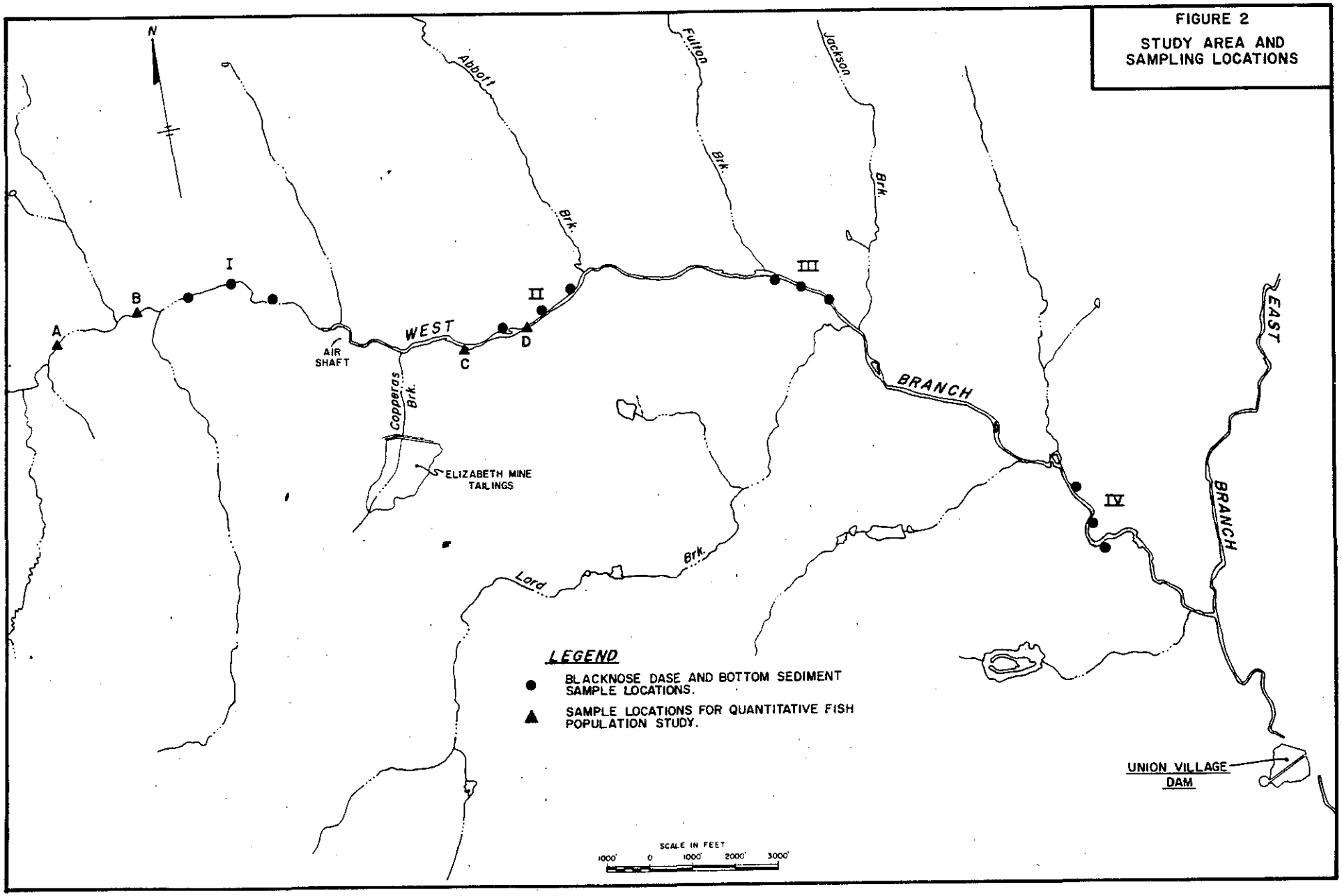


FIGURE 2
STUDY AREA AND SAMPLING LOCATIONS
N
Abbott Brk.
Fulton Brk.
Jackson Brk.
I
II
III
IV
A
B
C
D
AIR SHAFT
WEST BRANCH
EAST BRANCH
Copperas Brk.
ELIZABETH MINE TAILINGS
Lord Brk.
UNION VILLAGE DAM
LEGEND
BLACKNOSE DASE AND BOTTOM SEDIMENT SAMPLE LOCATIONS.
SAMPLE LOCATIONS FOR QUANTITATIVE FISH POPULATION STUDY.
SCALE IN FEET
1000' 0 1000' 2000' 3000'

Sediment samples were extracted with nitric and perchloric acid in accordance with EPA method 3020. Extracts were analyzed for metals using a Perkin Elmer Zeeman 5100 Atomic Absorption Spectrophotometer equipped with a graphite furnace.

Several method blanks, replicate samples, and spiked samples were analyzed to insure the accuracy and precision of the results. A fish tissue blank revealed no significant contamination of any metals, except lead. The lead level in the blank were such that no reliable estimate in lead in fish tissues can be presented. One tissue samples was analyzed in replicate to determine precision. Results were good for most metals, with relative differences between replicates ranging from 5 to 26 percent for Ba, Cd, Cu, Fe, Mn, and Zn. The relative difference for chromium was somewhat higher (42 percent). To determine accuracy, a tissue sample was analyzed after being spiked with known amounts of all the analytes. Recoveries were ranged between 96 and 106 percent for all metals, except Zinc, for which the recovery was 72 percent. A sediment sample was also analyzed in replicate. Results were excellent, with relative differences ranging from only 0.3 to 8.2 percent. Recovery of metals from a spiked sediment sample ranged from 76 to 115 percent.

Metal levels in fish and sediments from different sampling locations were compared statistically using a one way ANOVA and the T-method (Sokal and Rolf, 1981).

FISH COMMUNITY COMPOSITION AND BIOMASS

A quantitative fish population survey was also conducted. Two areas situated upstream of Elizabeth Mine drainage and two areas downstream of the confluence with Copperas Brook were sampled (see Figure 2). These areas were typical of upper reaches of the West Branch of the Ompompanoosuc in terms of percent instream and bank cover, percent riffle and pool, and substrate type. Areas selected for the population survey had not been disturbed by previous sampling for blacknose dace (see above). Segments of the river sampled ranged in length from 150 to 189 feet.

Sampling was conducted on July 6 and July 24-25, 1989. Seines were stretched across the upstream and downstream extremes of area sampled, and the entire reach was carefully electrofished with a backpack shocker. Captured fish were identified taxonomically, counted, and weighed. Stream widths were determined at several locations, and a brief habitat description of the area was recorded.

RESULTS AND DISCUSSION

BLACKNOSE DACE STUDY

Sediment Analysis

Elizabeth Mine drainage had a significant impact on copper levels in river sediments downstream of the mine (Table 1). Levels of copper in sediments at Area IV, the most heavily contaminated site, were 17.5 times those from upstream of the mine (Area I). Elevated copper levels were also found at Areas II and III. Zinc and manganese levels were also higher downstream of the mine, but highly variable, and not significantly different from levels at Area I. Mine drainage had no significant impact on levels of lead, iron, chromium, or barium in river sediments. Cadmium levels were generally below detection limits at all locations. Levels of copper, zinc, lead, and chromium were lower than reported for many freshwater sediments contaminated by mining operations (see Moore and Ramamoorthy, 1984).

Sediments from Areas I and IV were predominately very fine silty sands, while those from Areas II and III were predominately fine sands, with relatively low silt content. Silt content was highest at Area IV, where the river had broadened, and slower currents favored deposition of relatively fine grained sediments. Higher copper and iron levels at Area IV, relative to Areas II and III, probably reflect the high silt content of sediments at this location.

Blacknose Dace Tissue Analysis

Levels of copper, chromium, zinc, barium, and iron in dace collected downstream of the mine (Area IV) were significantly higher than those in fish from upstream of the mine (Area I, see Table 2). Metal levels in fish from Areas II and III were generally intermediate, and not significantly different from those in fish collected upstream of the mine.

Although results suggest that dace occurring downstream of the mine (Area IV) accumulate elevated levels of copper and other metals, this conclusion is tenuous. Iron does not bioaccumulate in tissues, and high levels found in dace at Area IV suggest that these samples were contaminated by fine sediments adhering to gills or other external surfaces. Such contamination would be most pronounced at Area IV because sediments at this location were relatively fine grained.

Elevated levels of other metals detected in dace downstream of the mine may result from similar external contamination, rather than bioaccumulation in tissues. Further analysis of tissues free of potential surface contamination (i.e. muscle

Table 1. Metal levels in Blacknose dace from the West Branch of the Ompompanoosuc River[1,2]

Metal	Location[3]											
	Area I			Area II			Area III			Area IV		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Barium	3.4	1.6	a	3.7	0.5	a	4.6	1.0	a	8.3	0.7	b
Cadmium	< 0.14	na		< 0.14	na		< 0.19	na		< 0.16	na	
Chromium	4.0	1.3	a	8.6	3.7	a	7.5	4.2	a	16.2	4.6	b
Copper	3.4	0.3	a	5.7	0.9	a	7.4	2.4	a,b	11.7	3.8	b
Iron	84.8	19.4	a	96.1	20.3	a,b	115	48	b	202	43	c
Lead	nd			nd			nd			nd		
Manganese	23.5	1.4	a,b	16.5	0.9	a	23.7	4.9	b	28.8	3.6	b
Zinc	186	9	a	173	10	a	215	34	a,b	233	8	b

1: all values in mg/kg dry weight

2: SE: standard error; values in the same row sharing a letter are not significantly different ($p < 0.05$, T-method)

3: see Figure 2 for sample locations

na: not available (some data points were undefined)

nd: no data available (high lead levels were noted in the method blank)

Table 2. Metal levels in Sediments from the West Branch of the Ompompanoosuc River[1,2]

Metal	Location[3]											
	Area I			Area II			Area III			Area IV		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Barium	38.3	4.1	a	26.4	6.8	a	38.3	12.6	a	36.4	9.0	a
Cadmium	< 0.5	na		< 0.8	na		< 0.8	na		< 1.1	na	
Chromium	22.3	2.6	a	17.3	2.3	a	20.4	4.8	a	22.6	4.2	a
Copper	6.0	1.3	a	57.5	11.5	b	46.8	7.4	b	105	1.0	c
Iron	15650	770	a,b	12925	1915	a	12590	2200	a	18700	1975	b
Lead	7.0	0.8	a	3.9	0.7	b	5.5	0.7	a,b	5.2	1.4	a,b
Manganese	389	96	a	358	53	a	385	113	a	507	63	a
Zinc	54.4	9.7	a	92.0	23.7	a	144	86	a	90.1	12.0	a

1: all values in mg/kg dry weight

2: SE: standard error; values in the same row sharing a letter are not significantly different ($p < 0.05$, T-method)

3: see Figure 2 for sample locations

na: not available (some data points were undefined)

tissue or internal organs) would be necessary to determine conclusively whether or not dace downstream of the mine have elevated metal levels.

No comparable published data concerning metal levels in blacknose dace is available for other locations. Levels of zinc and copper found in dace however, were within the range of whole-body values reported for several species of fish in a contaminated Mexican river (Villarreal-Trevino, et al. 1986). Levels of copper in that study were generally lower than reported for dace in the Ompompanoosuc.

Metal levels occurring in blacknose dace downstream of the mine are probably of little or no significance from an ecological or human health standpoint. There is little evidence in the literature that copper or the other metals tested in this study biomagnify in aquatic food chains (see reviews by Biddinger and Gloss, 1984; Kay, 1984; Moore and Ramamoorthy, 1984). Trout, which prey upon dace, are thus unlikely to contain much higher whole body metal levels than reported for dace in this study. Furthermore, levels of the tested metals in trout muscle are likely to be much less than whole body values, and would pose no risk to human health. It should be noted that this study was not able to test for mercury, which can biomagnify in aquatic food chains, and may be present at elevated levels in Ompompanoosuc waters downstream of the mine.

FISH COMMUNITY COMPOSITION AND BIOMASS

The fish community upstream of the mine (Areas A and B) was dominated by longnose dace, blacknose dace, and slimy sculpin (see Figure 3 and Table 3). Downstream of Copperas Brook (Areas C and D) brook trout and longnsoe sucker were the predominant species.

Mean fish standing crop (including trout) in the Ompompanoosuc was 4.7 kilograms/hectare upstream of the mine and 3.7 kg/ha at downstream stations. Mean forage species (dace, sculpin, and sucker) biomass was greatly reduced downstream of the mine (4.5 kg/ha upstream vs 1.3 kg/ha downstream). Forage species biomass is probably a better index of mine impacts on stream productivity than total fish biomass, because many of the trout occurring downstream of the mine are likely to be migrants from stocked tributary streams.

Blacknose dace collected downstream of the mine (Areas C and D) weighed significantly less ($p < 0.01$, t-test) and had a significantly shorter mean fork length ($0.01 < p < 0.05$) than fish collected from upstream stations (Areas A and B). A similar decrease in weight was not noted for longnose dace or slimy sculpins, but the sample size for these species below the mine was small.

Figure 3: Relative Biomass of Fish in the West Branch of the Ompompanoosuc Upstream and Downstream of the Elizabeth Mine.

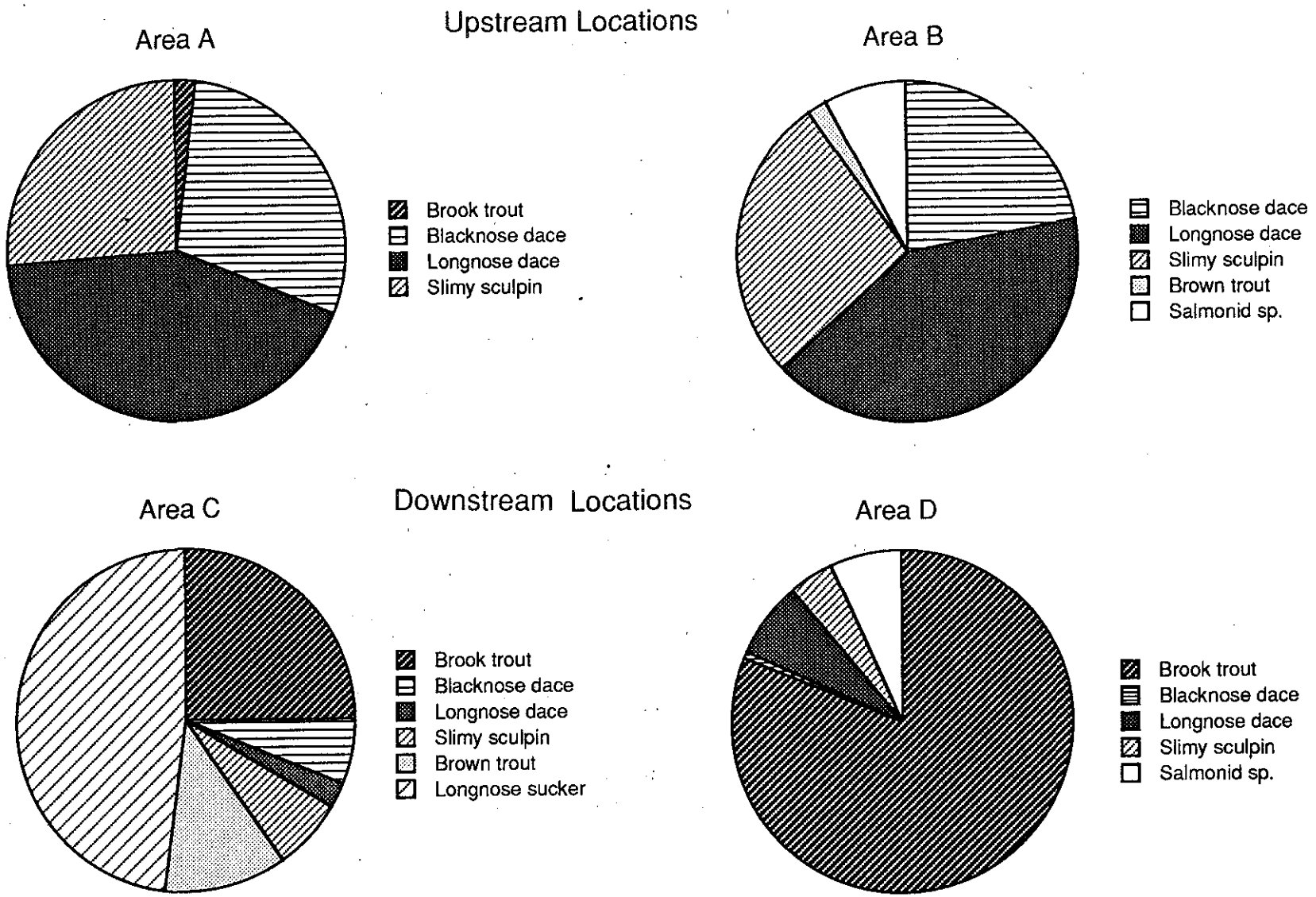


Table 3: Fish Community Composition and Biomass in the West Branch of the Ompompanoosuc River.

Species	Location[1,2] Area A[3] N	Area A Weight (g)	Area A Length (cm)	Area B[4] N	Area B Weight (g)	Area B Length (cm)
Longnose Dace (Rhinichthys cataractae)	40	3.5 (1.0-9.0)	6.5 (5.0-10.5)	18	4.0 (1.0-9.0)	7.0 (4.5-9.5)
Blacknose Dace (Rhinichthys atratulus)	35	3.0 (<1.0-8.0)	6.0 (3.5-7.5)	16	2.5 (1.0-5.0)	5.0 (3.5-7.5)
Slimy Sculpin (Cottus cognatus)	28	3.0 (1.0-6.0)	6.0 (4.5-8.0)	15	3.0 (1.0-7.0)	6.0 (4.0-9.0)
Brook trout (Salvelinus fontinalis)	1	6.5	5.0			
Brown trout (Salmo trutta)				2	2.0	5.0
unident. Salmonids[5]				2	6.5	10.5
Totals:	104	7.0 kg/ha		53	2.3 kg/ha	

1. see Figure 2 for location of sample sites
2. N: number caught; mean values and ranges given; length refers to "fork" length
3. Length of stream sampled: 150 ft; area sampled: 5130 sq. ft.
4. Length of stream sampled: 189 ft; area sampled: 8130 sq. ft.
5: fish escaped (lengths and weights estimated)

(continued on page 13)

Table 3: Fish Community Composition and Biomass in the West Branch of the Ompompanoosuc River (continued from page 12).

Species	Location[1,2] Area C[3] N	Weight (g)	Length (cm)	Area D[4] N	Weight (g)	Length (cm)
Longnose Dace (Rhinichthys cataractae)	3	2.0	6.0 (5.5-6.0)	4	5.0 (1.0-10.0)	8.0 (5.5-10.0)
Blacknose Dace (Rhinichthys atratulus)	9	1.5 (1.0-3.0)	5.0 (3.5-6.0)	2	< 1.0	4.5 (3.0-5.5)
Slimy Sculpin (Cottus cognatus)	7	2.5 (1.0-5.0)	5.5 (3.5-7.5)	2	6.5 (5.0-8.0)	7.5 (7.0-7.5)
Brook trout (Salvelinus fontinalis)	2	30.0 (15.0-45.0)	14.5 (13.5-15.5)	6	40.0 (<1-82.0)	14.0 (5.5-19.5)
Brown trout (Salmo trutta)	2	14.0 (5.5-13.0)	9.5 (2.0-26.0)			
Longnose Sucker (Catostomus catostomus)	8	14.5 (1.0-45.0)	12.5 (5.0-39.0)			
unident. Salmonids[5]				5	4.0	6.0
Totals:	31	3.4 kg/ha		19	3.9 kg/ha	

1. see Figure 2 for location of sample sites
2. N: number caught; mean values and ranges given; length refers to "fork" length
3. Length of stream sampled: 176 ft; area sampled: 7590 sq. ft.
4. Length of stream sampled: 165 ft; area sampled: 8110 sq. ft.
5: fish escaped (lengths and weights estimated)

The results of this study can be compared to two previous studies which investigated the impact of Elizabeth Mine drainage on the fisheries resources of the Ompompanoosuc River. Sampling conducted in 1987 by the Vermont Agency of Environmental Conservation (R. Langdon, pers. commun.) found that longnose dace, blacknose dace, and slimy sculpin were the most common species both upstream (near Area A) and downstream (near Area D) of the mine. As in this study, abundance of all three species, were greatly reduced downstream of the mine. In contrast to the current study, the DEC study noted few trout downstream of the mine. Trinchero (1980) found that white sucker (Catostomus commersoni), longnose dace, blacknose dace, slimy sculpin, and brook trout were the principal species present upstream of the mine. Stations sampled well downstream of Copperas Brook (from 2.2 miles downstream to near the confluence with the East Branch) were dominated by blacknose dace, white sucker, and longnose dace. As in this study, standing crop at stations upstream and downstream of the mine were similar.

The reduced abundance of dace and sculpins immediately downstream of the mine is probably primarily caused by the heavy deposits of tailings and other sediments on the river bottom. These sediments probably impact fish populations indirectly by reducing the abundance and availability of benthic invertebrate and algal prey. Fish populations may also be depressed because exposure to sublethal levels of metals in water and sediments can reduce the fish growth, survivorship, and ultimately fecundity. The possibility also exists that river waters may be acutely toxic to fish immediately downstream of the mine during exceptionally heavy runoff events. Aluminum and copper toxicity to fish eggs and larvae may be of particular importance.

SUMMARY

The results of this study provide evidence that the Elizabeth Mine has had a severe impact on the fisheries resources of the Ompompanoosuc River. The study showed that the biomass of forage species was dramatically reduced downstream of the mine. The study found no conclusive evidence, however, that blacknose dace downstream of the mine accumulate elevated levels of metals. River sediments downstream of the mine contain significantly higher copper levels than those from upstream stations. Mine drainage had no apparent significant effect on levels of other metals in river sediments.

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